Rehabilitation of the Atrophic Maxilla With Tilted Implants: Review of the Literature

David Peñarrocha-Oltra, DDS
Eugenia Candel-Martí, DDS
Javier Ata-Ali, DDS
María Peñarrocha-Diago, DDS, MD, PhD*

We review the evidence-based literature on the use of tilted implants in the rehabilitation of patients with maxillary atrophy. Studies from 1999 to 2010 on patients with atrophic maxilla rehabilitated with tilted implants were reviewed. Clinical series with at least 10 patients rehabilitated using tilted implants and a follow-up of at least 12 months after prosthetic load were included. Case reports and studies with missing data were excluded. In each study the following was assessed: surgical technique, prosthesis type, timing of implant loading, success rate and marginal bone loss of tilted and axial implants, complications and patient satisfaction level. Thirteen studies were included, reporting a total of 782 tilted and 666 axial implants in 319 patients. Success rates went from 91.3% to 100% for axial implants and from 92.1% to 100% for tilted implants; radiographic marginal bone loss went from 0.4 mm to 0.92 mm in tilted implants and from 0.35 mm to 1.21 mm in axial implants. No statistically significant differences were found in any of the studies. No surgical complications and only minor prosthetic complications were reported. High patient satisfaction was found with all types of prosthesis (full-arch fixed, partial fixed and overdentures) placed over tilted implants. The literature on tilted implants shows that implants placed with this technique, both used alone and combined with axially placed implants, and rehabilitated with different prosthetic options have high success rates, minimal complications and high patient satisfaction. However, lack of homogeneity among studies and relatively short follow-up periods for most studies make necessary more studies.

Key Words: tilted implants, angulated implants, angled implants, maxillary atrophy

INTRODUCTION

In the severely atrophic maxilla, alveolar ridge resorption, maxillary sinus pneumatization, presence of nasal cavities, and type 3 or 4 bone quality, according to Lekholm and Zarb classification,1 encumber or disable conventional dental implant placement. According to the original Bräñemark System concept implants should be placed fairly upright.2 Consequently, in a completely edentulous atrophic maxilla, long distal cantilevers would be necessary to provide the patient with acceptable chewing capacity in the molar regions; however, cantilevers longer than 15 mm have been associated with increased implant failure rates.3 Several treatment options have been proposed to solve this situation, including bone grafting techniques—block bone grafts and sinus lifting via crestal or lateral approach—and non-grafting techniques, which are modifications of the conventional implant procedure, such as placement in the zygomatic bone, the pterygoid process or the maxillary tuberosity, and use of short or tilted implants.4–7

Grafting procedures have higher complication rates, higher risk of morbidity, higher costs, and a longer delay until prosthetic rehabilitation, so patients may be reluctant to accept them.4 Furthermore, according to Widmark et al8 maxillary implants placed in native bone have a greater
success rate after 5 years (87%) than implants placed into grafted bone (74%). Zygomatic and pterygoid implants are alternatives to rehabilitate atrophic maxillas with high success rates, but require considerable surgical expertise and may be associated to increased morbidity. Short implants can also be placed to avoid the use of grafts, but it must always be taken into account when using these implants that a minimum bone height of 7–8 mm is needed anyway and that bone quality is a critical factor.

The technique of tilting implants in the residual crestal bone of patients with maxillary atrophy has been shown to provide several clinical advantages. It allows placement of longer implants, thus increasing implant-bone contact area and implant primary stability; anchorage into the dense bone adjacent to the anterior sinus wall also contributes to increased stability. Posterior tilting of distal implants increases the distance between anterior and posterior implants, thus reducing the need for distal cantilevers; biomechanically, the distalization of the implant platform reduces the moments of force and improves the load distribution. Furthermore, tilted implants may suppress the need for bone grafting procedures in some cases, thus reducing biologic and economic costs and leading to higher patient acceptance. On the other hand, finite element analysis on individual tilted implants shows higher stress on surrounding bone. However, it has been demonstrated that splinting of implants with fixed prosthetic structures reduces stress on peri-implant bone to a level similar to that around axial implants; therefore, to provide rigid support for the implants and minimize mechanical complications, it is recommended to use metal-reinforced prosthetic rehabilitations. Tilted placement, especially of posterior implants, may complicate the prosthetic treatment with respect to axially placed implants; however, the use of angulated abutments allows compensation for the implant angulation.

Several studies have reported the use of tilted implants to successfully rehabilitate patients both in the maxilla or the mandible. Testori et al placed 240 implants (80 tilted) in 40 patients with maxillary atrophy, obtained a success rate of 97.5% for tilted implants after a minimum 12-month follow-up, and concluded that this technique may serve as a minimally invasive modality to rehabilitate resorbed maxillae with high patient acceptance. Similarly, Weinstein et al rehabilitated 20 atrophic mandibles with fixed full-arch prostheses over 2 axial and 2 tilted implants, and obtained a 100% survival rate after 12 months. In a recent review Del Fabbro et al found no statistically significant differences between tilted and upright implants, nor between maxillary and mandibular tilted implants; however, 25 implants (1.25%) failed within the first year, of which all except one were maxillary. Due to worse bone quality, maxillary implants have a higher failure risk than those placed in the mandible, and tilted placement may be an additional risk-increasing factor. Furthermore, Att et al performed a review of the different treatment approaches for fixed rehabilitation of the atrophic maxilla, including tilted implant placement; they considered 8 studies regarding tilted implants but, with the exception of 1 study, all reported combined survival rates of axial and tilted implants and did not provide exclusive data about the tilted implants. This suggests that further study of the outcomes of tilted implants in the maxilla is necessary, with a separate assessment from axial implants (placed in the same maxillae) and from tilted implants in the mandible.

The objective of this report is to review the evidence-based literature on the use of tilted implants in the rehabilitation of patients with maxillary atrophy.

**MATERIAL AND METHOD**

A data search was performed using PubMed’s electronic databases of dental reports and reviews of clinical studies, using the following search terms in simple or multiple conjunctions: “tilted implants,” “angled implants,” “angulated implants,” “inclined implants,” and “maxillary atrophy.” The years searched were 1999 to 2010. Review articles and references from different studies were used to identify relevant studies.

To select the studies all obtained reports were reviewed. Titles and abstracts were screened for relevance. The full text of relevant abstracts was obtained and screened using the following inclusion and exclusion criteria.
Inclusion criteria:
- Use of tilted implants
- Clinical series of at least 10 patients
- Follow-up of at least 12 months after prosthetic load

Exclusion criteria
- Case reports
- Studies with missing data
- Studies in languages other than English or Spanish

The initial literature search yielded 118 articles. After the first screening based on the title and abstract, 22 studies were found eligible. Full-text review of these studies determined the selection of 13 articles for analysis. Six were prospective single-cohort studies and eight had a retrospective design. No randomized clinical trials were found.

In each study the following were assessed: type of study, sample size, follow-up time, surgical technique, prosthesis type and implant loading, success rate and marginal bone loss of tilted and axial implants, complications, and patient satisfaction level (Table 1).

Results
Thirteen studies were included, reporting a total of 782 tilted and 666 axial implants in 319 patients.

In the articles reviewed, implant lengths ranged from 7 mm to 20 mm. Implants of 7 mm to 9 mm were only placed by 2 authors: Mattsson et al placed 18 of the 7-mm tilted implants; Balleri et al placed 3 tilted implants of 8 mm and 3 implants of 9 mm. All the remaining authors placed implants with lengths between 10 mm and 20 mm. Tilted implants placed in the studies reviewed had diameters between 3.6 mm and 4.2 mm. The follow-up period comprised between 12 and 144 months.7,16,17,20–29 The number of patients, number of tilted and axial implants, length, and diameter are detailed in Table 1.

It must be pointed out that evidence of the results of this review is limited by the lack of homogeneity among studies, which hinders carrying out a systematic review. Some compared tilted with axial implants while others only considered tilted implants, and study type, prosthesis types, and timing of implant loading were very variable within the considered studies. Furthermore, the follow-up period was relatively short in several of the studies.16,22,26–28

Surgical technique
The technique of tilting implants allows for implant placement in residual bone in all directions and advantage can be taken of different anatomic locations, including the bone palate, the maxillary sinus anterior and posterior walls, the maxillary tuberosity, the pterygoid process, the nasal spine and the nasal floor.7,21

Mattson et al published the first series of 15 patients treated with 86 tilted implants. Each patient received 1 posterior tilted implant on each side parallel to the anterior sinus wall, 2 more axial implants in the sinus-nasal wall, and 1 or 2 anterior angulated implants anchored into the nasal spine. They fenestrated the lateral wall of the maxillary sinus to determine the position of the anterior wall before placing a tilted implant parallel and close to it. Several authors have thereafter used this technique of drilling a small exploratory window before placing tilted implants parallel to the anterior sinus wall, and similarly before placing implants parallel to the posterior sinus wall.17,20,26,29

Mattson et al also elevated the nasal cavity mucosa to explore the cortical bone of the nasal floor before placing implants in this area.

Maló et al described the All-on-four technique to rehabilitate atrophic maxillae using only 4 implants, 2 axial anterior, and 2 tilted posterior implants placed parallel to the anterior sinus wall. The description of this technique included drilling of a small window to determine the position of the anterior sinus wall, and tilted implants were placed with the aid of a specially designed surgical guide.

Other authors have described less invasive techniques that avoid perforation of the lateral sinus wall. Calandriello et al and Agliardi et al performed intra-operative radiographs to confirm that the drilling direction was correct, that the implant site was completely surrounded by bone and there was no risk of sinus membrane perforation. Peñarrocha et al combined drills and osteotomes to place 48 tilted implants in the anterior maxillary buttress in severely atrophic maxillae. The osteotome technique preserves bone, provides more tactile control to the surgeon and reduces surgical risks.

Several authors considered implants as tilted
when their angulation was of 15° or more with respect to the vertical plane. Other studies placed implants with an inclination of about 30° from the vertical plane. Aparicio et al specifies that tilted implants were placed with a mean mesiodistal inclination of 35° and usually combined with buccopalatal inclination of 15°, with some extreme inclinations over 50°. Calandriello et al placed 27 tilted implants: 23 were angulated more than 30° posteriorly to bypass the sinus, and 4 implants were tilted less than 30° to avoid the nasal fossa. Balleri et al placed 20 tilted implants in the retrocanine bone triangle with an average inclination of 23.4° and range of 8.4° to 38.3°.

Not only mesiodistal implant tilting has been described; to achieve good primary implant stability in thin (<4 mm wide) marginal crests, already in 1984, Branemark et al placed implants in a palatal position, with threads left uncovered on the palatal side. In several studies reviewed implants were palatally tilted to take advantage of bone that always remains in the palate; these implants were left with 2–5 threads uncovered on the palatal side, but in no case did this lead to mucosal problems or marginal bone resorption.

### Table 1

<table>
<thead>
<tr>
<th>Reference</th>
<th>Type of study</th>
<th>No. Patients</th>
<th>No. Axial implants</th>
<th>No. Tilted implants</th>
<th>Length and Diameter (mm)</th>
<th>Angulation (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mattson</td>
<td>Retro</td>
<td>15</td>
<td>NA</td>
<td>86</td>
<td>7–18</td>
<td>NA</td>
</tr>
<tr>
<td>Krekmanov</td>
<td>Retro</td>
<td>22</td>
<td>98</td>
<td>40</td>
<td>3.75</td>
<td>30–35</td>
</tr>
<tr>
<td>Aparicio</td>
<td>Retro</td>
<td>25</td>
<td>59</td>
<td>42</td>
<td>13–20</td>
<td>&gt;15</td>
</tr>
<tr>
<td>Maló</td>
<td>Retro</td>
<td>32</td>
<td>64</td>
<td>64</td>
<td>10–15</td>
<td>17–30</td>
</tr>
<tr>
<td>Calandriello</td>
<td>Prosp</td>
<td>18</td>
<td>33</td>
<td>27</td>
<td>10–15</td>
<td>&gt;15</td>
</tr>
<tr>
<td>Rosén and Gynther</td>
<td>Retro</td>
<td>19</td>
<td>NA</td>
<td>103</td>
<td>NS</td>
<td>&gt;30</td>
</tr>
<tr>
<td>Testori</td>
<td>Prosp</td>
<td>40</td>
<td>160</td>
<td>80</td>
<td>NS</td>
<td>30–35</td>
</tr>
<tr>
<td>Agliardi</td>
<td>Prosp</td>
<td>61</td>
<td>122</td>
<td>122</td>
<td>10–18</td>
<td>30–45</td>
</tr>
<tr>
<td>Agliardi</td>
<td>Prosp</td>
<td>20</td>
<td>40</td>
<td>80</td>
<td>11.5–15</td>
<td>30–45</td>
</tr>
<tr>
<td>Hinze</td>
<td>Prosp</td>
<td>19</td>
<td>38</td>
<td>38</td>
<td>NS</td>
<td>&gt;13</td>
</tr>
<tr>
<td>Penarrocha</td>
<td>Retro</td>
<td>12</td>
<td>NA</td>
<td>48</td>
<td>3.6, 4.2</td>
<td>30–35</td>
</tr>
<tr>
<td>Balleri</td>
<td>Retro</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>8–15</td>
<td>23.4 (8.4–38.3)</td>
</tr>
<tr>
<td>Francetti</td>
<td>Prosp</td>
<td>16</td>
<td>32</td>
<td>32</td>
<td>NS</td>
<td>4</td>
</tr>
</tbody>
</table>

MBL indicates marginal bone loss; NA, not applicable; NS, not specified; Retro, retrospective; Prosp, prospective; FAF, full-arch fixed; PF, partial fixed; OD, overdenture.

### Prosthetic design and loading

In the first study on tilted implants by Mattson et al patients were rehabilitated with complete-arch fixed prostheses supported by 4 to 6 implants that were allowed to heal for at least 6 months before abutment connection; the same procedure was later followed by Rosén and Gynther. Afterwards, Maló et al described the All-on-four immediate function concept to rehabilitate edentulous patients immediately (within the same day of the surgery) with provisional full-arch, fixed, all-acrylic prostheses over 4 implants—2 tilted and 2 axial. According to this technique tilting the posterior implants makes possible to position the implant head in second premolar/first molar position, thus enabling rehabilitation with a fixed prosthesis over 4 implants with only a short cantilever. Other studies have thereafter reported successful results using the All-on-four immediate function concept to rehabilitate atrophic maxillae. However, other authors consider successful results more predictable using 6 implants, axial and tilted, to support immediately loaded, fixed, full-arch prostheses.
Tilted implants have also been used to rehabilitate partially edentulous patients with partial fixed prostheses using both immediate\(^2\)\(^2\) and delayed loading.\(^7\)\(^,\)\(^2\)\(^8\) Calandriello et al\(^2\)\(^2\) immediately loaded implants in partially edentulous patients using screw-retained temporary prostheses delivered the day of the surgery or after a few days; early loading was applied in full-arch restorations, and in all cases final prostheses were delivered 4 to 6 months postsurgery. In the study by Balleri et al\(^2\)\(^8\) second surgeries were performed 6 months after surgery and all 20 patients were rehabilitated with three-unit screw retained, fixed partial dentures with acrylic veneers; in 6 cases a small cantilever was required to completely restore the occlusal table. Aparicio et al\(^2\)\(^1\) performed abutment connection 6 to 8 months after implant placement and rehabilitated 25 patients with 29 fixed partial screw-retained prostheses supported by 2 to 5, tilted and axial, implants; prostheses had neither distal nor mesial cantilevers. Prosthesis type and implant loading are detailed in Table 1.

One study was found that used tilted implants to support overdentures: Peñarrocha et al\(^2\)\(^7\) rehabilitated 12 patients with severe maxillary atrophy with overdentures over bars supported by 4 implants; second surgery was carried out 2 months after implant surgery and prosthodontic treatment began 1 to 2 months later.

### Success rate

The success of implants was assessed using Albrektsson’s clinical and radiologic criteria by several authors,\(^1\)\(^7\),\(^2\)\(^0\),\(^2\)\(^1\),\(^2\)\(^3\),\(^2\)\(^7\) other authors evaluated implant survival.\(^7\)\(^,\)\(^1\)\(^6\),\(^2\)\(^2\),\(^2\)\(^4\)–\(^2\)\(^6\),\(^2\)\(^8\),\(^2\)\(^9\) In the literature reviewed success rates went from 91.3% to 100% for axial implants and from 92.1% to 100% for tilted implants; no statistically significant differences were found in any of the studies. In total 19 tilted and 22 axial failed implants were reported, yielding overall weighted success rates of 97.6% and 96.4% respectively. Success rates for tilted and axial implants in the studies reviewed are detailed in Table 1.

Agliardi et al\(^2\)\(^4\) reported in 2009 the longest clinical series in the literature: 61 maxillas were rehabilitated using 4 implants, 2 anterior axial implants and 2 posterior tilted implants parallel to the anterior maxillary sinus wall; the survival rate was 100% for both axial and tilted implants after an average follow-up period of 27.2 months. In another study the same authors rehabilitated 20 maxillas

<table>
<thead>
<tr>
<th>Surgical technique</th>
<th>Success axial implants (%)</th>
<th>Success tilted implants (%)</th>
<th>MBL axial implants (mm)</th>
<th>MBL tilted implants (mm)</th>
<th>Follow-up (months)</th>
<th>Prosthesis type</th>
<th>Implant loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drills</td>
<td>NA</td>
<td>98.8</td>
<td>NS</td>
<td>NS</td>
<td>45 (36–54)</td>
<td>FAF</td>
<td>Delayed</td>
</tr>
<tr>
<td>Drills</td>
<td>92.5</td>
<td>95.7</td>
<td>NS</td>
<td>NS</td>
<td>(53) 35–60</td>
<td>PF</td>
<td>Delayed</td>
</tr>
<tr>
<td>Drills</td>
<td>91.3</td>
<td>95.2</td>
<td>0.92 (after 5 years)</td>
<td>1.21 (after 5 years)</td>
<td>37 (21–87)</td>
<td>FAF</td>
<td>Delayed</td>
</tr>
<tr>
<td>Drills</td>
<td>100</td>
<td>95.3</td>
<td>NS</td>
<td>NS</td>
<td>12</td>
<td>FAF</td>
<td>Immediate</td>
</tr>
<tr>
<td>Drills</td>
<td>97.0</td>
<td>96.3</td>
<td>0.82±0.86</td>
<td>0.34±0.76</td>
<td>12–48</td>
<td>PF</td>
<td>Immediate</td>
</tr>
<tr>
<td>Drills</td>
<td>NA</td>
<td>97.0</td>
<td>NA</td>
<td>1.2 (after 8–12 years)</td>
<td>96–144</td>
<td>FAF</td>
<td>Immediate</td>
</tr>
<tr>
<td>Drills</td>
<td>98.1</td>
<td>97.5</td>
<td>0.9±0.4</td>
<td>0.8±0.5</td>
<td>22, 5</td>
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<td>Immediate</td>
</tr>
<tr>
<td>Drills</td>
<td>97.5</td>
<td>99.2</td>
<td>NS</td>
<td>NS</td>
<td>31.3 (12–59)</td>
<td>FAF</td>
<td>Immediate</td>
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<tr>
<td>Drills</td>
<td>100</td>
<td>100</td>
<td>0.9±0.5</td>
<td>0.8±0.4</td>
<td>27.2 (18–42)</td>
<td>FAF</td>
<td>Immediate</td>
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<tr>
<td>Drills and osteotomes</td>
<td>92.1</td>
<td>92.1</td>
<td>0.82±0.31</td>
<td>0.76±0.31</td>
<td>12</td>
<td>FAF</td>
<td>Immediate</td>
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<tr>
<td>Drills</td>
<td>NA</td>
<td>97.9</td>
<td>NA</td>
<td>0.78±0.5</td>
<td>12</td>
<td>OD</td>
<td>Delayed</td>
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<tr>
<td>Drills</td>
<td>100</td>
<td>100</td>
<td>0.4</td>
<td>0.35</td>
<td>12</td>
<td>PF</td>
<td>Delayed</td>
</tr>
<tr>
<td>Drills</td>
<td>100</td>
<td>100</td>
<td>0.44±0.37 (after 2 years)</td>
<td>0.63±0.38 (after 2 years)</td>
<td>33.8 (22–40)</td>
<td>FAF</td>
<td>Immediate</td>
</tr>
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</table>
using 6 implants, 2 anterior axial implants and 4 tilted implants, 2 parallel to the anterior sinus wall and 2 parallel to the posterior wall; after 31.3 months average follow-up 97.5% of the axial implants and 99.2% of the tilted implants survived. Other authors have reported high success rates with both delayed and immediately loaded full-arch prosthesis.

High success rates have also been reported for tilted implants rehabilitated by fixed partial prostheses and overdentures. Aparicio et al obtained respective success rates of 91.3% and 95.2% for axial and tilted implants rehabilitated with fixed partial restorations after an average follow-up period of 37 months. Peñarrocha et al rehabilitated 12 patients with overdentures supported each by 4 tilted implants, and only 1 implant had failed after 12 months, yielding a success rate of 97.9%.

Despite implant failures all studies reviewed reported 100% prosthesis success rates, and also reported that surviving implants that did not fulfill the success criteria were functional and could be used to support the prostheses.

**Bone loss**

Bone loss in tilted implants was assessed by 8 authors: Hinze et al measured bone loss in calibrated panoramic radiographs; other authors used intraoral radiographs made with the paralleling technique. Marginal bone loss of tilted and axial implants in the studies reviewed is detailed in Table 1.

Peñarrocha et al assessed bone loss in panoramic radiographs calibrated with Cliniview (Version 5.1, Tuusula, Finland) after the surgery and a year after loading, giving an average marginal bone loss of 0.78 mm for 48 tilted implants. Rosén and Gynther published the series with the longest follow-up: they reported an average bone loss of 1.2 mm after 8 to 12 years; 10% (10) of the implants presented bone resorption larger than that acceptable according to the criteria of Albrektsson et al ($\leq 1$ mm during the first year after loading and $\leq 0.2$ mm each year thereafter).

Several authors have compared bone loss between tilted and axial implants. Aparicio et al measured bone loss in intraoral radiographs using the prostheses placement radiograph as baseline at the mesial and distal aspects of each implant and then calculated a mean value to the closest half thread: They reported average bone losses of 0.92 mm and 1.21 mm for axial and tilted implants respectively after 5 years of follow-up, with no statistically significant differences. Agliardi et al also averaged mesial and distal values to provide a single value for each implant but used peri-apical radiographs after implant placement as baseline; the radiographs were scanned (Epson Perfection Pro, Epson) and the marginal bone level assessed with an image analysis software (UTHSCSA Image Tool version 3.00 for Windows, University of Texas Health Science Center at San Antonio) by an independent blinded radiologist. They obtained an average bone loss of 0.9 mm for axial implants and of 0.8 mm for tilted implants in the one-year control visit, exhibiting no statistically significant differences. Similarly in the study by Calandriello et al radiographs were digitized with a scan (Epson 1240, 800 dpi) and bone loss was measured with an image analysis program (NIH Image Version 4.0.2, Scion Corp, Frederick, Md) by an independent radiologist; radiographics were repeated in cases of nonreadable examination. They reported changes in bone level of 0.82 $\pm$ 0.86 mm and 0.34 $\pm$ 0.76 mm for axial and tilted implants respectively after 1 year, being the only series reporting statistically significant differences. The authors suggested that the lower bone resorption observed in tilted implants may be related to the position of the implant neck relative to the bone crest; mesially the neck was in supracrestal position, while distally it was subcrestal, resulting in a favorable soft tissue seal.

**Complications**

No surgical complications were mentioned in the studies reviewed, and only Rosén and Gynther reported postoperative biological complications. They observed local mucositis in 9 patients, 8 of which expressed problems maintaining optimal oral hygiene. Three patients suffered postoperative sinusitis during the first year; in 1 of these patients patient nasal floor infection and sinusitis were caused by an implant that had penetrated the nasal mucosa, while in the other 2 sinus problems occurred only once or twice and could not be associated with the implant treatment.

Several authors reported prosthetic complications; however, these were all considered minor and most could be solved without removing the
prostheses: Aparicio et al\textsuperscript{21} reported 28 mechanical incidents in 16 prosthesis (55.2%): 18 and 5 of these incidents were respectively abutment and gold screw retightenings, 2 were abutment screw fractures and 1 was a fracture of occlusal material. Hinze et al\textsuperscript{26} found that after 12 months the most common technical complication was acrylic veneer material fracture in provisional prostheses (10.8%), followed by loss of screw access hole restorations (9.5%) and occlusal screw loosening (6%). For Agliardi et al\textsuperscript{25} and Francetti et al\textsuperscript{29} the only prosthetic complication was the fracture of the acrylic prostheses, which occurred in 10 (16.4%) and 3 (19%) cases respectively; Testori et al\textsuperscript{17} only found screw loosenings, which occurred in 7 (17.5%) provisional prostheses, in 3 tilted and 4 axial implants. Calandriello et al\textsuperscript{22} reported crack propagation and subsequent fracture of the acrylic bridge in 1 case, which was only one in which implant failures (1 tilted and 1 axial) were recorded. Malò et al\textsuperscript{16} only recorded fractures of prostheses in 4 bruxing patients, of whom two were patients who lost 1 implant each.

**Patient satisfaction**

Patient satisfaction level was assessed by 5 authors.\textsuperscript{7,17,23,25,27} Already in 1999, Mattson et al\textsuperscript{7} found 100% satisfaction with aesthetics of prostheses supported by tilted implants; in their study 4 patients complained of phonetic problems after prosthesis placement, but at the 1-year follow-up these were no longer perceived as socially limiting. The study by Peñarrocha et al\textsuperscript{27} was the only one that rehabilitated patients with overdentures; they used a visual analogue scale from 0 to 10 to estimate patient satisfaction 12 months after loading and obtained an average overall satisfaction of 8.5. All patients were satisfied with comfort and stability (8.0), ability to speak (9.0), ease of cleaning (8.5), esthetics (8.5) and function (8.5). In the study by Testori et al\textsuperscript{17} Twenty-eight patients completed a satisfaction questionnaire in the 1-year follow-up visit. A total of 75% patients considered esthetics as excellent or very good, and 21.4% as good. Mastication was considered excellent or very good by 69.2% and good by 30.8% of the patients. Phonetics was excellent or very good for 85.7% of the patients and sufficient for 14.3%. Ease of maintenance was considered excellent or very good for 35.7% of the patients, good for 42.9%, sufficient for 14.3% and poor for 7.1%. Rosén and Gynther\textsuperscript{23} treated 19 patients with fixed prosthesis supported by only tilted implants and no patient had chewing problems; 1 patient had trouble biting in the front, 8 patients reported temporary speaking trouble and 7 problems with esthetics. Agliardi et al\textsuperscript{25} evaluated satisfaction 1 year after prosthesis placement: Esthetics was judged as excellent or very good by 83.4% of the patients, while phonetics and mastication were considered excellent or very good by 91.7% and 75% of the subjects respectively.

**CONCLUSIONS**

The literature on tilted implants shows that implants placed with this technique, both used alone and combined with axially placed implants, and rehabilitated with different prosthetic options have high success rates, minimal complications and high patient satisfaction.

However, studies available compare different surgical methods of placement and types of prostheses. They also vary in implant lengths, type of occlusion, loading protocol and study design. This lack of homogeneity limits the relevance of the conclusions that can be drawn. Furthermore, follow-up periods for most studies are relatively short, thus impeding the comparison of the outcome of tilted and axially placed implants in the long term. Prospective studies with long follow-ups are necessary to support the successful results of tilted implants.

**REFERENCES**


